



Draft: EARTHSHIPS and CONSTRUCTION OVERVIEW

Earthships use recycled automotive tires filled with rammed earth to create unique, energy-efficient structures. Traditional Earthships are self-contained systems which meet 100% of their energy needs through solar and wind, harvest rainwater for both domestic/potable and irrigation, recycle greywater, utilize composting toilets, and grow food within the home in an integrated greenhouse.

The Earthship system was developed by Michael Reynolds of New Mexico, where numerous structures have been built. Earthships have been built in Coconino County utilizing Reynolds' blueprints, which can be ordered through Earthship Biotecture: <http://earthship.com>. Due to our unique climatic and seismic location, Earthships built within Coconino County must adhere to the following code requirements:

1. Foundations: Shall be 18 inches into undisturbed soil and shall be 30 inches in depth to meet the County requirements for frost depth. Footings shall have poured concrete equal to the width of the tire walls.

****Any more details needed?***

2. Walls: ***Should we reference OR use parts from Reynolds' guide below, AND/OR keep it as a separate section as it is now?***

(A) Tires must be compacted to a minimum of 90% with compactable soil; granite must be screened.

(B) The bottom course of the tire wall shall be pinned to the foundation with #4 rebar with one (1) pin in the center of each tire. These pins should be embedded into the foundation to a depth of not less than seven inches (7") and shall extend XX inches (XX") vertically out of the foundation as a structural connection to the tires at XX feet on center and within XX inches of all corners.

****RE: bond beams - Section 7 below?***

(C) Each subsequent course of tires shall have XX rebar XX tires that extend vertically through that course and halfway into the second adjacent course below, penetrating a total of XX courses. Rebar shall be driven into the tires at XX maximum with laps no less than XX minimum. All rebar shall be located approximately XX from the end of the wall.

(D) Exterior walls will be covered with an appropriate moisture barrier (2-layers 15# felt, or equivalent), followed by stucco-mesh or metal lath (with screws or nails through aluminum roofing disks), then stucco or other approved plastering material finish in three layers.

3. Roof: An earthen roof with concrete requires the structure to be stamped by an AZ registered architect. No engineering is required for Earthships with conventional roofing.

4. Each sleeping area (bedroom) must have egress directly to the exterior either through a door, a window, or an exit device with a minimum clear dimension of 22 inches, a minimum clear opening of five (5) square feet, and a sill height of no more than 36 inches. (AzDBSFR)

5. A smoke detector is installed in all rooms or hallways providing access to sleeping rooms and in each sleeping room. The detectors may be battery-operated or hard-wired with battery back-up and installed according to manufacturer's specifications. (AzDBSFR)

The following is adapted from Earthship Biotecture, NM:

<http://earthship.com/Codes-Regulations-Laws/Tire-Building-Code-dp1>

1. TIRE SIZES USED IN BEARING AND RETAINING WALLS

A. Automobile tires come in sizes called 13, 14, 15 and 16. These sizes relate to the radius of the tire in inches, #13 tires being the smallest tires used in a bearing or a retaining wall and #16 tires being the largest. These sizes will be specified in different parts of the structure as such.

B. The first course of tires must be as large in diameter, or larger in diameter, than any other tire in the wall. No tire may appear in a wall that is larger in diameter than the tires on the ground course of that wall.

C. Tire walls over six (6) courses high must have a ground course of tires #15 or larger *exclusively*.

2. COURSING

A. All tire walls must use staggered running bond coursing.

B. Joints between tires on any given course must be aligned with the central area of all tires on courses above and below. No joint between tires on any given course may align with any joint on the courses above or below.

C. Half tire techniques as outlined in Article 4 must be used to maintain running bond coursing.

3. HALF TIRE TECHNIQUES

A. CONCRETE HALF TIRES

Concrete half tires must use a mix of 3 parts cement / 4 parts sand / 5 parts gravel with engineering fibers. All tires adjacent to concrete half blocks must be "porcupined" (see *EARTHSHIP VOL.3*, pages 2-4) with 16d nails to lock concrete to tires. In that concrete half tires are the most substantial half tire method, they will be specified in some situations by the architect. All two-story tire wall applications will use concrete half tires.

B. RAMMED EARTH HALF TIRES

Rammed earth half tires are made by cutting a tire in half and leaving tabs on the sides to screw into the adjacent tire. This half tire is then pounded like a regular tire. Rammed earth half tires can be used only in tire walls five (5) courses high or less and *never* at the end of a wall.

4. FILL OF WALLS

A. Earth rammed tires walls can be filled or rammed with any type of earth, clay, sand or rock fill.

B. All tire casings must be packed tight to 90% compaction with a 6# to 9# sledge hammer. Soft spongy tire packing is not acceptable.

5. VOID FILLING

A. All voids between tires in earth rammed tire walls must be packed solid with mud in a four (4) coat

procedure described in *EARTHSHIP VOL. 1*, pages 174-175, unless specific conditions require this packing to be done with concrete as per Article 10 of this code.

6. BEARING WALLS

A. Bearing walls built from earth rammed automobile tire casings must follow Articles 1 through 4 of this code.

B. All bearing walls built from earth rammed automobile tire casings must have a continuous bond beam of wood or concrete as described in *EARTHSHIP VOL. 1*, pages 101-103 or *EARTHSHIP VOL. 3*, pages 6-9.

C. All bearing walls built from earth rammed automobile tire casings which are eight (8) courses or higher for their entire length must have a continuous bond beam that connects to a continuous bond beam on adjacent non-bearing tire walls.

7. PLATES AND BOND BEAMS

A. All tire walls that are an integral part of the roofed building shall have a continuous wood or concrete bond beam. This bond beam shall be anchored to the tire wall with 1/2" anchor bolts set in concrete every other tire or 1/2" rebar driven down through three (3) courses of tires and bent over the top of the wood plate or set in the concrete bond beam.

B. Wood bond beam plates shall be no less than four inches (4") thick and twelve inches (12") wide. Wood bond beam plates can be made up of (2) 2" x 12"s with 6 mil plastic between the rammed earth tire wall and the wood bond beam plate. The bottom bond beam plate must be treated lumber. Joints in the lower layer of lumber shall never be closer than 2'-0" away from joints in the upper layer of lumber. Upper and lower layers of lumber shall be laminated with (6) 16d nails per running foot.

C. Concrete bond beams shall be a minimum of 8" deep x 8" wide and have two pieces of 1/2" rebar continuous.

8. OPENINGS IN WALLS

A. All openings in walls made of earth rammed automobile tires shall have concrete half blocks on either side of the opening.

B. The wood or concrete bond beam spanning the opening shall be increased in thickness by a minimum of eight inches (8"). This additional thickness shall extend on either side of the opening a minimum of 2'-4" and shall set on and be anchored to a concrete bearing block equivalent in thickness to the tire coursing height.

9. JOINTS

A. All joints and connections in earth rammed tire walls must be designed and assembled in such a way so that no voids occur within the earth rammed tire wall. These voids must be filled with concrete or 90% compacted earth contained in a double layer of metal lath or a rubber tire casing.

B. All joints and connections in earth rammed tire walls must employ over lapped tires and joining methods so as not to result in stacked joints occurring over each other.

10. TWO STORY

A. All two story earth rammed tire structures shall be designed by a licensed architect or engineer.

B. A continuous 9" deep x 2'-0" wide concrete bond beam must occur at each floor level.

C. All tires on the first level must be #15 or larger.

D. All tires on the second level must be #14 or smaller.

- E. All blocking must be concrete.
- F. All void packing on the first floor level walls must be concrete.
- G. All earth rammed tire work must follow Articles 1 through 4 of this code.

11. LENGTH OF WALLS

A. There is no limit to the length of earth rammed tire walls, since rammed earth tire walls are not made of a rigid material that is sensitive to expansion/ contraction cracks.

12. HEIGHT OF WALLS

A. The maximum height for a straight earth rammed tire wall which is an integral part of a structure with a roof or floor load is ten feet (10'). At this point a wood or concrete bond beam must be installed as per Article 7 of this code.

B. The maximum height for a circular earth rammed tire wall which is an integral part of a structure with a roof or floor load is twelve feet (12'). At this point a wood or concrete bond beam must be installed as per Article 7 of this code.

C. The maximum height for a free standing earth rammed tire wall that is not a curved or a battered retaining wall or otherwise structurally integrated into a building is six feet (6').

D. There is no maximum height for a battered retaining wall constructed from earth rammed tires. All battered retaining walls must be engineered by a licensed architect or engineer.

13. LOADING OF WALLS

A. Loading on earth rammed tire walls must be distributed loading only from joists, beams or rafters setting on a continuous wood or concrete bond beam as per Article 7 of this code.

B. No point or collected loading is possible on earth rammed tire walls unless special engineering is provided by a licensed engineer or architect.

C. The limits of the evenly distributed load an earth rammed tire wall can accept are determined by the bearing capacity of the soil that the earth rammed tire wall is setting on. In cases where an earth rammed tire wall is setting on rock or a concrete foundation which is wider than the tire wall itself and more than typical roof or second story loading is desired, the bearing capacity of the tire wall will be determined by a licensed architect or engineer.

14. RETAINING WALLS

A. All retaining walls built from earth rammed automobile tires must follow Articles 1 through 4 of this code.

B. All retaining walls built from earth rammed automobile tire casings must be stepped back or lean into the earth they are retaining.

C. Specifications and construction drawings certified by a licensed architect or engineer must appear in the stamped construction drawings for the permitted building for all retaining walls built from earth rammed automobile tire casings.

15. FREE STANDING WALLS

DEFINITION: Any wall not tied into the roof structure of a building.

A. All free standing walls built from earth rammed automobile tire casings must follow Articles 1 through 4 of this code.

B. All free standing walls over two (2) courses high built from earth rammed automobile tire casings must have continuous arcs built into the design of the wall. These walls cannot be straight for any distance.

C. Free standing walls built of earth rammed automobile tire casings cannot be over five (5) courses high unless designed by an architect and certified specifications and construction drawings are provided for that wall.

16. EARTH CLIFFS

A. All earth cliffs shall be at a minimum distance of twelve inches (12") from an earth rammed tire wall.

B. All earth cliffs shall be approved as a result of site and soil inspection by a licensed architect or engineer.

The regulations for earth rammed tire construction put forth in this code are a guideline relating to structure only and are subject to evolution, refinement, and addendum.

Other useful links:

<http://www.greenhomebuilding.com/earthship.htm> Excellent site offering books, video links, photos, and floor plans as well as other web-links

<http://www.touchtheearthranch.com/tirestart.htm> Another earthship site with links

<http://www.ecologycenter.org/factsheets/greywater-cleaning-products.html> Green products for greywater systems

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